
The effectiveness of several market integration measures when facing a market turmoil

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Practical applications

This paper illustrates how to use and calculate in practice a significant number of integration measures that allow the comparison of different markets (mainly spot and futures markets) in which closely related securities are traded. The value of the integration measures at a given date provides practical rules in order to choose the best market to invest in according to price/return criteria. It also yields useful information with respect to lead and lag relationships between markets, as well as practical procedures to explore the existence of cross-market arbitrage available for traders.

Abstract

Many market integration measures are operationalised to compute their numerical values during a period characterised by lack of stability and market turmoil. The results of the tests give

their degree of effectiveness, and reveal that measures based on the principles of asset valuation, versus statistical measures, more clearly yield the level of integration of financial markets. Moreover, cross-market arbitrage-linked measures

and equilibrium models-linked measures provide complementary information and reflect different properties, and, consequently, both types of measures may be useful in practice.

INTRODUCTION

The integration of financial markets is an issue of special interest that has been the objective of numerous papers comparing stock markets, bond markets, foreign exchange markets, commodity markets and derivative markets. A high degree of integration among markets indicates that prices are formed in a correct way and, therefore, agents interested in well-diversified portfolios and appropriate risk-return ratios will concentrate on the available assets without taking into account the concrete markets. Furthermore, if derivative markets are involved, low cost operations can be carried out, possibly helping to attract more investors to hedged or deferred positions, increasing market liquidity. Conversely, a low degree of integration implies quite different pricing rules with the subsequent effect on the diversification process. It can also dissuade hedged positions and leads to arbitrage strategies that generate riskless profits derived from discrepancies in prices. Finally, some agents can implement speculation strategies that take profits from the greater predictive power of one market over another one.

Several authors have viewed integration

as a market phenomenon, or alternatively, as a public policy induced phenomenon.¹ Despite the interest of this concept, a rigorous definition of what is understood by integrated markets does not exist in the financial literature and it is only commonly accepted as an intuitive but imprecise idea: two financial markets are integrated when they evolve in a combined way. Many authors try to formalise the concept and provide numerical and analytic integration measures. Several questions arise. For instance, under which conditions are they equivalent? Is any one superior to the rest? Do the responses to these questions depend on the concrete setting?

Theoretical and empirical approaches may be applied to answer these questions. The different market integration measures can be classified into two major categories according to their nature. The first group contains those measures introduced by statistical and econometric methods, while the second one focuses on the asset pricing theory. This kind of classification is introduced for the first time in this paper. The purpose is to analyse the convenience of considering the financial theory to introduce an integration measure. In short, 11 integration measures are revised: three based on statistical techniques and eight on the basic principles of asset valuation.

All the measures based on statistical and econometric techniques analyse the

integration between two concrete markets within a time interval and require a wide sample period. They do not provide information on the arbitrage strategy to implement in order to take advantage of the lack of integration, nor do they consider the transaction costs that would be incurred when carrying it out. Otherwise, measures based on the principles of asset valuation are of particular interest since they can be applied at any moment in time and, in some cases, they provide an optimum arbitrage strategy.

The measures based on theoretical approaches may be subdivided in measures based on cross-market arbitrage and measures based on equilibrium models. Cross-market arbitrage-linked measures seem to be more adequate when derivatives are involved and hedging or deferred strategies are the focus of the analysis. Equilibrium-linked measures are useful when studying very incomplete markets and looking for well-diversified portfolios, although data for long periods are required in order to compute some of these measures. Thus, arbitrage and equilibrium arguments apply in different settings and reflect different properties, confirming that both sorts of measures may be considered to analyse integration levels.

This paper presents a set of empirical tests that analyses the effectiveness of a large number of measures in a situation of clear disintegration. In order to guarantee the lack of integration, the Spanish index

IBEX-35 and its derivative market have been chosen during a period characterised by market turmoil. These markets have shown a high degree of efficiency, as pointed out by Lee and Mathur.² However, Balbás, Longarela and Pardo³ detected a large number of cross-market arbitrage opportunities during the Asian crash of October 1997. The applied procedure guarantees maximal precision since perfectly synchronised high frequency data have been used to compute the value of the market integration measures.

The main result of the tests shows that measures based on the principles of asset valuation provide a similar degree of integration, minute-by-minute, during the tested period, while the rest of the measures contradict each other. This seems to imply a serious objection for the statistical measures that are not able to give a unified conclusion and, consequently, asset-pricing models could yield a more successful way to measure the level of market integration.

The paper is structured as follows. The next section summarises some integration measures based on statistical and econometric techniques. Then follows a description of the measures based on cross-market arbitrage, and a review of equilibrium-linked measures. Next, the measures are applied to the IBEX-35 futures market during the Asian crash (October 1997), and finally a conclusion is drawn.

MEASURES BASED ON STATISTICAL AND ECONOMETRIC TECHNIQUES

The first set of measures is based on statistical and econometric methods. The most widely used and intuitive measure is the cross-correlation of contemporary returns of the compared markets. So, the first measure of economic integration can be stated as follows.

Measure 1

Following Kempf and Korn,⁴ spot-futures market integration can be measured by the cross-correlation coefficient between simultaneous returns and the cross-correlation coefficients for the spot return with the futures return at different lags. The higher the contemporaneous coefficient and the minor lagged correlation coefficient, the stronger the market integration is.

A correlation coefficient near to one would indicate perfect integration between both markets, since they incorporate the information in the same manner. A zero or negative correlation coefficient would imply segmentation.

It should be emphasised that cash market frictions grant some comparative advantages to the futures market, which have led some authors to analyse whether prices in the futures market lead or lag those in the spot market. Consequently, different works study the dynamics between the price returns of market indexes and their future contracts, applying either the causality of Granger⁵ or the causality of Sims.⁶ For this last case, the

regression equation is

$$c_t = \alpha + \sum_{k=-p}^p \beta_k f_{t-k} + u_t \quad (1)$$

where c_t and f_t indicate the returns of the cash and of the derivative assets at the date t , respectively, and k is the number of lags. The coefficients with negative (positive) subscripts indicate lag (lead) coefficients. The degree of market integration is deduced, in this case, from the β_k values.

Measure 2

The markets are integrated if the contemporary variable coefficient β_k is greater than zero and all other coefficients are not different from zero. Significant values for the coefficients at lags k would indicate that the returns in the futures markets tend to lead those in the spot market, and significant values for the coefficients at leads k would indicate that the futures market tends to lag the spot market.

It should be pointed out that measures 1 and 2 are characterised for the use of returns (first differences in prices). This causes some inconvenience when spot and futures prices form a cointegrating vector.⁷ For this reason, the development of cointegration techniques at the end of the 1980s resulted in a new integration measure based on prices and not on returns.

Measure 3

Two markets are integrated if a cointegrating structure between them exists.

The study of the integration between the derivative market and its underlying asset through cointegration analysis lies on the relationship between arbitrage and cointegration. Pricing based on arbitrage must duplicate one asset with another (or a combination of other) asset(s). Hence, if the derivative asset follows a certain trend, the arbitrage activity should cause the underlying asset to share the same trend. Consequently, as Arshanapalli and Doukas⁸ pointed out, 'cointegration [...] would imply that the deviation from the common equilibrium path should cause price realignments, restoring the original equilibrium. On the other hand, lack of cointegration between the index futures and the underlying cash market would suggest that the underlying forces which are required to integrate the two markets into one market are rather weak'.

The Granger Representation Theorem establishes that if the price series of the two comparative markets are cointegrated, the short-run adjustments of the series with regard to the equilibrium level are included in an error correction model. If spot and derivative asset prices are cointegrated, then either spot prices lead derivative prices, or derivative prices lead spot prices or a combination of the two effects exists. For this reason, measure 3, together with measures 1 and 2, have been applied to measure the integration between markets and to check a possible lead-lag relationship (see Sutcliffe⁹ for a complete survey of the

empirical studies of leads and lags between spot and futures prices and Stephan and Whaley¹⁰ and De Jong and Donders¹¹ for the case of relationships between spot and options markets).

MEASURES BASED ON CROSS-MARKET ARBITRAGE

The first studies to outline the integration between derivative markets and their underlying assets following the basic principles of asset valuation placed great emphasis on checking the fulfilment of the Law of One Price (see Protopapadakis and Stoll,¹² Cornell and French,^{13,14} Modest and Sundaresan¹⁵ and Modest¹⁶). Consequently, the derivative asset has to be duplicated (or the underlying asset from the market price of the derivative asset) and the theoretical price has to be compared with its market price. Since the asset and its replica must offer the same payoffs, the equality between these prices indicates the fulfilment of the Law of One Price (LOP). Of the above-mentioned, an integration measure p that compares the deviation between the theoretical spot price (C'_t) and the spot price (C_t) can be defined as

$$p = \frac{C'_t}{C_t}. \quad (2)$$

Measure 4

If p is equal to one, the LOP is fulfilled and the markets are integrated. Conversely, if p is larger (smaller) than one, the cash

asset is undervalued (overvalued) with regard to its replica obtained from the derivative contract and the risk-less bond.

This measure allows the incorporation of the transaction costs involved in the arbitrage strategy. It also permits the study of market integration between the futures market and the underlying market, between the options market and the cash market and between the futures and the options markets if these last two have a futures contract as an underlying asset.

Recently, Chen and Knez¹⁷ have introduced a new approach to analyse the degree of market integration. They define the concept of market integration in a weak and a strong sense and establish the corresponding measures. Two markets are integrated in a weak sense if the LOP is fulfilled between them.

Measure 5

Consider two markets, A, and B, in which the LOP holds separately. The weak integration measure $g(A, B)$ is defined as the smallest difference between each market's family of state prices and it is calculated as

$$g(A, B) = \min_{d_A \in D_A, d_B \in D_B} \|d_A - d_B\|^2 \quad (3)$$

where D_A and D_B are the sets of state prices for each market and $\| \cdot \|$ is the Euclidean norm. If $g(A, B) = 0$, the markets are integrated in a weak sense, while if $g(A, B) > 0$ the markets are not integrated

and arbitrage opportunities exist. Since the fulfilment of the LOP does not imply the absence of arbitrage opportunities (AAO), Chen and Knez¹⁷ restrict the concept of integration and establish that two markets are integrated in a strong sense if cross-market arbitrage opportunities do not exist between them.¹⁸ They define a new integration measure.

Measure 6

Consider two markets, A and B, in which there are no arbitrage opportunities in either market. The integration measure in a strong sense is defined as the smallest difference between the positive state prices and it is calculated as

$$a(A, B) = \min_{d_A \in D_A^+, d_B \in D_B^+} \|d_A - d_B\|^2 \quad (4)$$

where D_A^+ and D_B^+ are the sets of positive state prices for each market. If $a(A, B) = 0$, the markets are integrated in a strong sense, while markets are not integrated and arbitrage opportunities exist as long as $a(A, B) > 0$.

Measures g and a represent an important advance on the measures based on statistical and econometric techniques and on measure p , since they inform about market integration by considering all possible arbitrage portfolios and they are not based on concrete strategies.¹⁹ Nevertheless, the two integration measures proposed by Chen and Knez¹⁷ are based on differences in state

prices and, therefore, they do not allow the transaction costs to be discounted.

Balbás and Muñoz,²⁰ following the approach by Chen and Knez,¹⁷ propose two new integration measures based on monetary terms. They use the benefits that can be obtained from the optimal arbitrage strategy, if it exists. To obtain this measure, they consider a one-period model (t, T) , and a unique market that incorporates all the markets that they compare; n assets are traded at a price p_i with $i = 1, 2, \dots, n$, at the date t . A portfolio x is defined as $x = (x_1, x_1, \dots, x_n)$ where the x_i indicates the bought (positive sign) or sold (negative sign) units of the asset i . All the assets take prices that are known at moment T assuming a discrete source of uncertainty K . If the states of nature are H , only one of them can occur at T . The price of portfolio x at moments t and T are given, respectively, by

$$P(x) = \sum_{i=1}^n x_i p_i \text{ and } \alpha_x(k) = \sum_{i=1}^n x_i \alpha_i(k)$$

where $\alpha_i(k)$ indicates the pay-off of the asset i in the state of the nature k . Theorem 3 of Balbás and Muñoz²⁰ proves that when LOP fails, then there exists a solution x^* for the following optimisation problem

$$\text{Maximise } f(x) = \frac{-\sum_{i=1}^n x_i p_i}{-\sum_{i \in S_x} x_i p_i}$$

$$\text{subject to } \begin{cases} \sum_{i=1}^n x_i \alpha_i(k) = 0 \text{ for every } k \in K \\ \sum_{i=1}^n x_i p_i < 0 \end{cases}$$

where S_x represents the set of the sold assets of portfolio x (ie $x_i < 0$). The numerator of the objective function is the value of the arbitrage portfolio and the denominator is the aggregate amount of the sales, both expressed in monetary units at moment t . If the solution is reached at x^* the quotient can be interpreted as the ratio between the benefit obtained from the arbitrage strategy x^* and the value of the sold assets. The first constraint implies that at the moment T the portfolio has a payoff equal to zero in all states of nature. The second constraint looks for portfolios that provide an income at the moment t . Notice that the set of opportunities of the problem is the set of possible arbitrage portfolios. The integration measure is defined by $m = f(x^*)$ and takes values between 0 and 1. As a result, the new integration measure is as follows.

Measure 7

If m is equal to zero, the LOP holds and the markets are integrated. If m takes values greater than zero, arbitrage opportunities exist and the markets are not integrated.

It is possible that arbitrage opportunities exist even when m is equal to zero. To detect them, it is only necessary to modify the sign of the first constraint of the previous problem, imposing the search for a portfolio whose payoffs at T are larger than

or equal to zero in all the states of nature. In this case, the optimal value will be denoted by M . Therefore, following the terminology of Chen and Knez,¹⁷ m and M could be considered the weak and strong integration measures proposed by Balbás and Muñoz.²⁰ Thus, there is a new integration measure.

Measure 8

If M is equal to zero, the markets are integrated in a strong sense. If M takes a value greater than zero, arbitrage opportunities exist and the markets are not integrated.

The measures m and M denote the integration of the market in a global sense, since they consider all the possible arbitrage strategies and they choose the optimal one. Moreover, these measures do not need to make assumptions about the fulfilment of the LOP or about the AAO on each market, because all the analysed assets are included in only one market.

The use of integration measures based on profits facilitates the consideration of the transaction costs paid when carrying out an arbitrage strategy. If l is defined as the quotient between the benefit of the arbitrage portfolio (B) and to the sum of the purchase (P) and sold (S), a relationship between l and m can be stated,

$$l = \frac{B}{P + S} = \frac{m}{2 - m}.$$

Assume that the total transaction costs (T)

incurred in arbitrage-related strategies are proportional to total value of the exchanged assets quantities and define the ratio TC as the ratio $T/(P + S)$. The difference between l and TC indicates the unitary profit obtained from the arbitrage once the transaction costs have been discounted. The consideration of the transaction cost is a fundamental issue when determining if the markets are integrated or not. Arbitrage opportunities can exist, indicating that the markets are not integrated ($m > l > 0$), but they cannot be exploited since the profit would not compensate the transaction costs ($TC > l$). It is interesting to highlight that if l is equal to TC we have

$$m' = \frac{2(TC)}{1 + TC}$$

where m' is an implicit measure of integration that indicates the minimum value that m must take so that arbitrage opportunities do not exist. Or, in an alternative sense, the maximum value that m can take so that the market is integrated.

Therefore, significant results are obtained with the Balbás and Muñoz²⁰ integration measures: the composition of the optimal portfolio and the possibility to discount the transaction costs.

MEASURES BASED ON EQUILIBRIUM MODELS

The second group of measures based on the principles of asset valuation are

measures based on equilibrium models. Garbade and Silber²¹ collected this feature in the measure they suggested for testing the integration level between the cash and futures markets. These authors specified a dynamic equilibrium model and they established that the degree of market integration is a function of the elasticity of supply of arbitrage services that can be measured from the following model:

$$C'_t - C_t = \alpha + \delta(C'_{t-1} - C_{t-1}) + \varepsilon_t \quad (5)$$

where C'_t is the natural logarithm of the theoretical spot price, C_t is the natural logarithm of the observed spot price and δ is an inverse measure of the elasticity of supply of arbitrage services. 'In the context of equation [...] δ measures the rate of convergence of cash and futures prices' (Garbade and Silber, p. 294²¹) and is the next measure of integration.

Measure 9

If δ is small, both markets are integrated and prices will converge quickly. If δ is equal to 1, both markets are not linked and the futures and spot prices will follow uncoupled random walks.

Wang and Yau²² note that 'although Garbade and Silber²¹ have provided a model to estimate the rate of convergence of cash and futures prices which reflects the corresponding level of index arbitrage activities, they do not furnish a statistical test for the significance of the estimated

coefficients, [...] which has profound implications in the testing for market linkage'. Hence, Wang and Yau,²² Yadav²³ and Kempf and Korn⁴ have outlined the estimation of δ testing for the presence of a unit root in the mispricing series, defined as the difference between theoretical and market prices. Thus, we have a new measure of integration derived from the previous one that would be obtained by testing for the presence of a unit root in the following model:

$$\Delta M_t = \alpha_0 + \gamma M_{t-1} + \sum_{i=1}^p \gamma_p \Delta M_{t-p} + \xi_t \quad (6)$$

where $M_t = C'_t - C_t$ and γ shows the mean reversion in mispricing. Its value is the following integration measure.

Measure 10

If there is not a unit root in the mispricing series (ie $\gamma < 0$), markets are linked. If there is a unit root (ie $\gamma = 0$), spot and futures price series are not related and the markets are not linked. The higher the mean reversion parameter (γ), the stronger the market integration is.

In this case, the integration is again wholly related to the existence of arbitrage opportunities. If the previous mispricing was positive (the spot price was underpriced), arbitrage activity would force the change in the mispricing to be negative (the underpricing would decline) and vice versa.²⁴

Yadav, Pope and Paudyal²⁵ and Dwyer, Locke and Yu²⁶ have generalised the mean

reversion analysis by applying a cost of carry model with non-zero transaction costs to motivate estimation of threshold models between futures and cash indexes. Their results suggest that the speed of convergence of the basis to its equilibrium value depends on the level of mispricing.

Bessembinder²⁷ proposed the latest measure that is reviewed in this paper. This author establishes that assets and futures markets are integrated if expected returns on portfolios consisting of asset and futures positions are identical to expected returns on asset-only portfolios of identical systematic risk.

The relationship between the expected next period return on the i th asset, $E_{t-1}(R_{it}^a)$ and its systematic risk is stated as

$$E_{t-1}(R_{it}^a) = \gamma_{it} + \beta_{it-1}^a \gamma_{1t} \quad (7)$$

where γ_{it} is a cross sectional constant, $\beta_{it-1}^a \gamma_{1t}$ is a $1 \times n$ vector of conditional sensitivities of i asset to each of n economic variables and γ_{1t} is a $n \times 1$ vector of risk premiums at time t .

The behaviour of futures prices in a model of capital market equilibrium obeys the relation:

$$E_{t-1}(R_{it}^f) = \beta_{it-1}^f \gamma_{1t} \quad (8)$$

where $\beta_{it-1}^f \gamma_{1t}$ is a $1 \times n$ vector of conditional sensitivities of percentage change in futures prices j to the n economic variables.

Since (7) holds for spot prices and (8) holds for futures, expected returns of portfolios composed of assets and futures are also given by (7). Thus, market integration implies that the futures premium and the expected excess return on the spot asset differ only if the systematic risk of the spot and futures markets differ. To evaluate this, conditional betas are estimated and are used to make cross sectional regressions of the form:

$$R_{pt} = \gamma_{0t} + \gamma_{0t}^* d_p + \sum_{i=1}^n [\gamma_{it} \hat{\beta}_{ipt} + \gamma_{it}^* \hat{\beta}_{ipt} d_p] + \varepsilon_{pt}$$

where R_{pt} is the return on equity portfolio or futures contract p , $\hat{\beta}_{ipt}$ is the estimated beta for portfolio p with respect to the i th economic variable, and d_p is a dummy variable equal to zero for spot assets and equal to unity for futures contracts.

The hypothesis that futures markets are fully integrated with assets markets is checked by testing that risk premiums are uniform across assets and futures markets, and that the intercept for futures contracts is zero.

Measure 11

The markets are integrated if we cannot reject that the estimates of γ_{it}^* and the estimates of $\gamma_{it}^f \equiv \gamma_{it} + \gamma_{it}^*$ are equal to zero.

In short, measures 9, 10 and 11 only study the integration between the spot and futures markets. They have similar characteristics to the measures based on

econometric techniques but, unlike them, they have to take into account some equilibrium model.

Table 1 shows the different financial integration measures described in this paper and a summary of some of their characteristics.

EMPIRICAL ANALYSIS

The IBEX-35 futures market (MEFF-RV) began to trade in January 1992 and since then it has consolidated itself as one of the most important in Europe.²⁸ The stock and futures markets are electronic and the priority for crossing a transaction is determined by price. If prices are equal, priority is given to the arrival time of the order.

The minute-by-minute data prices used in this study make reference to the period between 22nd October and 30th October, 1997 (seven market sessions). On Thursday 23rd October, 1997, the Hang Seng index of the Hong Kong Stock Exchange suffered a fall of 10.41 per cent, which in turn caused a generalised drop in the European markets. Specifically, the beginning of the crisis of the Asian financial markets at the end of October 1997 caused large variations in the closing prices, high intraday volatilities and unprecedented trading volumes in the Spanish stock and futures markets (see Table 2). All this justifies the choice of this period for the study of the financial integration between the two

markets, comparing a stable sub-period (22nd, 23rd and 24th October) with an unstable sub-period (27th, 28th, 29th and 30th October).²⁹ The delays, stops and extensions of the trading session in several market sessions have led to the adjustment of the sample period for the seven days. Consequently, the degree of financial integration between stocks and stock index futures has been determined daily.

The minute-to-minute prices of the IBEX-35 index and the midquote of the bid and ask price of the futures contract on IBEX-35, with expiration on the 21st November, 1997, have been obtained from the Market Information System (MIS) of MEFF-RV. The Sociedad de Bolsas provided the dividends paid out by the IBEX-35 index shares and the interest rates have been obtained from the Servicio de Series Temporales del Banco de España. Because intraday data were not available for interest rates, the daily middle rate corresponding to the repo operations carried out with Spanish Treasury Bonds has been chosen for all the minutes of the same day.

Measures based on statistical and econometric techniques

The cross correlation analysis of the minute-by-minute returns for IBEX-35 spot and IBEX-35 futures is presented in Table 3. The contemporary correlation coefficients (measure 1) are significant at the 1 per cent level every day, except 29th

Table 1: Integration measures between a financial market and its derivatives markets

<i>Measures based on statistical and econometric techniques</i>		<i>Measures based on the asset pricing theory</i>		<i>Measures based on equilibrium models</i>
		<i>Measures based on cross-market arbitrage</i>		
Series in differences	Series in levels	Fulfilment of the Law of One Price	Fulfilment of the Law of One Price and Absence of Arbitrage Opportunities	Garbade and Silbers model ²¹
Cross-correlation technique	Engle-Granger test for cointegration ⁷	Relationship between future contract and its underlying asset	Measures of weak and strong integration of Chen and Knez ¹⁷	Mean reversion of the mispricing series
Granger causality ⁵	Cointegration procedure proposed by Johansen ^{31,32} and Johansen and Juselius ³³	Put-call parity	Measures of weak and strong integration of Balbás and Muñoz ²⁰	Tests of futures markets integration of Bessembinder ²⁷
<i>Characteristics</i>		<i>Characteristics</i>		<i>Characteristics</i>
Integration for one period		Integration level for a fixed date		Integration for one period
Lead-lag relationships can be established		Lead-lag relationships cannot be established		Lead-lag relationships cannot be established
Medium, last transaction or closing prices		Bid and ask, medium, last transaction or closing prices		Medium, last transaction or closing prices
Transaction costs cannot be taken into account		Transaction costs can be taken into account	Transaction costs cannot (resp., can) be taken into account by measures of Chen and Knez ¹⁷ (resp., Balbás and Muñoz) ²⁰	Transaction costs cannot be taken into account
Relationships between concrete markets		Concrete strategies	Non-predetermined strategies	Concrete strategies

Table 2: Statistics for the Ibex-35 cash index and the Ibex-35 futures contract

The first column shows the variables whereas the results for the corresponding day appear on the remaining columns. The second row shows the number of observed returns. The third row gives the close-to-close variation of the IBEX-35 stock index. The fourth (fifth) row gives the IBEX-35 stock index (IBEX-35 futures contract) volatility obtained as the standard deviation of the minute-to-minute returns. The sixth row provides the spot returns autocorrelation coefficient (ρ_{spot}) and its p -value appears in parentheses. The seventh row gives the autocorrelation coefficient of the futures returns (ρ_{fut}) and its p -value appears in parentheses. The eighth row shows the relative bid-ask spread of the futures contract (S_{fut}). The ninth and tenth rows give the transaction volume on the spot and futures market in millions of pesetas and number of contracts, respectively.

VARIABLE	22	23	24	27*	28*	29*	30
Observations	415	415	415	415	401	379	407
Variation (%)	-0.40	-2.49	-0.79	-4.40	-4.18	5.66	1.12
σ_{spot} (%)	0.046	0.063	0.056	0.074	0.125	0.078	0.090
σ_{fut} (%)	0.049	0.069	0.047	0.084	0.235	0.117	0.118
ρ_{spot}	0.077	0.085	0.197	0.192	0.147	0.233	0.327
	(0.115)	(0.083)	(0)	(0)	(0.003)	(0)	(0)
ρ_{fut}	0.115	0.037	0.007	0.139	0.175	0.131	0.245
	(0.019)	(0.455)	(0.88)	(0.004)	(0)	(0.01)	(0)
S_{fut}	0.05	0.05	0.05	0.06	0.11	0.07	0.06
Vol _{spot}	138433.35	124031.96	82628.55	102194.46	218310.71	151003.4	148770.57
Vol _{fut}	21525	30179	22351	38374	93130	54816	61231

*Asian crisis

October. For this day we cannot reject the segmentation hypothesis between markets ($H_0: \rho_{\text{spot}, \text{fut}} = 0$) at the 1 per cent level. In the non-contemporary cross correlation analysis we observe that, first, every day presents a cross correlation between spot price changes and one-minute lagged futures price changes ($\rho_{\text{spot}, \text{fut}(-1)}$) significant at the 1 per cent level and higher than the contemporary correlation. Secondly, the coefficients with $k > 0$ are significant only

starting from 28th October. These results suggest that new information tends to be reflected first in futures market in stable periods, while during the Asian crisis a bi-directional effect is observed. According to the second measure, therefore, 22nd, 23rd and 24th October show the highest degree of integration.

Before estimating a bivariate model to determine the degree of market integration that measure 2 proposes, it is important to

Table 3: Cross-correlation of minute-to-minute intraday returns

Cross-correlation of minute-to-minute intraday returns for stock index and stock index futures. The first and last columns show the number of lags (k). The rest of the columns gives the cross correlation $\rho_{\text{spot}, \text{fut}(k)}$ for the corresponding day. The t -statistic appears in parentheses. The numbers in bold are significant at the 1 per cent level.

k	22	23	24	27*	28*	29*	30	k
-5	-0.001 (-0.024)	0.036 (0.735)	-0.001 (-0.014)	0.083 (1.691)	0.189 (3.789)	0.012 (0.232)	0.057 (1.156)	-5
-4	0.138 (2.809)	0.027 (0.548)	0.051 (1.037)	0.064 (1.306)	0.168 (3.368)	0.123 (2.389)	0.077 (1.547)	-4
-3	0.154 (3.127)	0.047 (0.947)	0.023 (0.477)	0.123 (2.512)	0.177 (3.548)	0.164 (3.199)	0.208 (4.190)	-3
-2	0.210 (4.276)	0.110 (2.231)	0.229 (4.667)	0.249 (5.081)	0.211 (4.223)	0.277 (5.395)	0.408 (8.233)	-2
-1	0.360 (7.338)	0.448 (9.126)	0.478 (9.729)	0.476 (9.701)	0.224 (4.492)	0.235 (4.579)	0.512 (10.323)	-1
0	0.246 (5.005)	0.333 (6.782)	0.334 (6.800)	0.297 (6.052)	0.136 (2.723)	0.116 (2.266)	0.430 (8.669)	0
1	0.091 (1.852)	-0.008 (-0.163)	0.007 (0.147)	0.125 (2.544)	0.193 (3.859)	0.101 (1.972)	0.193 (3.900)	1
2	0.060 (1.220)	-0.011 (-0.230)	0.096 (1.954)	0.070 (1.428)	0.116 (2.315)	0.074 (1.439)	0.002 (0.042)	2
3	-0.023 (-0.477)	-0.013 (-0.261)	0.046 (0.937)	0.024 (0.493)	0.120 (2.403)	0.154 (3.004)	0.004 (0.073)	3
4	0.031 (0.623)	0.085 (1.734)	-0.054 (-1.106)	0.013 (0.261)	0.018 0.364	0.110 (2.134)	-0.015 (-0.305)	4
5	-0.045 (-0.921)	0.001 (0.014)	-0.017 (-0.336)	-0.075 (-1.536)	-0.020 -0.398	-0.060 (-1.166)	-0.179 (-3.607)	5

*Asian crisis

remember that this measure uses returns as variables (first differences in prices). Following Engle and Granger,⁷ if the cash

and futures series were cointegrated, a bivariate model expressed in first differences would not be well specified. Hence, the

Table 4: Phillips-Perron test for unit roots in stock index and stock index futures prices

Z_L is the Phillips-Perron statistic of the series in levels and Z_D is the Phillips-Perron statistic of the series in first differences. For a model with intercept the MacKinnon critical values are -2.868 and -3.448 at the 1 per cent and 5 per cent levels, respectively.

Panel A: lpc_t

	22	23	24	27*	28*	29*	30
Z_L	-1.348	-1.296	1.820	-1.898	-2.319	-0.872	0.147
Z_D	-18.880	-18.725	-16.390	-17.096	-17.964	-16.080	-14.894

Panel B: lpf_t

	22	23	24	27*	28*	29*	30
Z_L	-1.186	-1.236	2.332	-0.601	-0.605	-0.484	-0.393
Z_D	-18.160	-19.525	-20.300	-17.742	-16.754	-16.731	-15.612

*Asian crisis

existence of a cointegration relationship between the cash and futures prices on the IBEX-35 index has been analysed. The null hypothesis of a single unit root is tested for each of the IBEX-35 spot and futures prices using the non-parametric test of Phillips and Perron (see Table 4).³⁰ Although the null hypothesis is not rejected for the price series at the 5 per cent level, it is for the series in differences at the 1 per cent level.

Once proven that both series are integrated of the same order, we have tested for the existence of a stationary linear combination of them (measure 3) by applying the multivariate methodology proposed by Johansen^{31,32} and by Johansen and Juselius.³³ Table 5 reports the

cointegration results. The null hypothesis of no cointegration is rejected at the 10 per cent level and, therefore, the existence of at least one cointegration vector cannot be rejected. These results dissuade the use of integration measure number 2. Highlighted in Table 5 is the fact that the null hypothesis is rejected at the 10 per cent level on 29th October and at the 5 per cent level on 27th and 28th October, while the remaining days it is rejected at the 1 per cent level. Therefore markets appear to have been highly integrated under normal trading conditions.

After detecting the existence of a cointegration vector, an error correction model has been estimated for each day.³⁴

Table 5: Johansen cointegration test results for stock index and stock index futures price

The first column shows the corresponding day and the number of observations and lags are in parenthesis. $\hat{\lambda}_i$ ($i = 1, 2$) is the estimated value of the characteristic root (eigenvalue). The last column gives the statistic $\hat{\lambda}_{trace}$ that tests the null hypothesis, which, versus a more general alternative, considers that the number of distinct cointegration vectors is lower or equal to r . Each day has an intercept in a cointegration equation. 24th October and 30th October have intercept and deterministic trend. *, ** and *** denote significance at the 1 per cent, 5 per cent and 10 per cent level, respectively. Critical values of the $\hat{\lambda}_{trace}$ statistic are obtained from Osterwald-Lenum.

Day	H_0	$\hat{\lambda}_i$	$\hat{\lambda}_{trace}$
22	$r = 0$	0.058	28.153*
(416,6)	$r \leq 1$	0.009	3.657
23	$r = 0$	0.116	52.992*
(416,3)	$r \leq 1$	0.006	2.301
24	$r = 0$	0.078	33.943*
(416,4)	$r \leq 1$	0.001	0.578
27	$r = 0$	0.052	24.361**
(416,4)	$r \leq 1$	0.006	2.286
28	$r = 0$	0.052	22.556***
(402,9)	$r \leq 1$	0.004	1.600
29	$r = 0$	0.029	13.229**
(380,7)	$r \leq 1$	0.006	2.341
30	$r = 0$	0.062	26.625*
(408,7)	$r \leq 1$	0.003	1.082

The model that has finally been constructed, according to the Johansen procedure^{31,32} is as follows,

$$\Delta lp c_t = c_1 + \gamma_1 \tilde{z}_{t-1} + \sum_{i=1}^p a_{1i} \Delta lp c_{t-i} + \sum_{i=1}^p a_{2i} \Delta lp f_{t-i} + u_{1t}$$

(9)

$$\Delta lp f_t = c_2 + \gamma_2 \tilde{z}_{t-1} + \sum_{i=1}^p b_{1i} \Delta lp c_{t-i} + \sum_{i=1}^p b_{2i} \Delta lp f_{t-i} + u_{2t}$$

where $lp c_t$ and $lp f_t$ indicate the natural logarithm of the prices of the last transaction of the series of the IBEX-35

Table 6: Error corrections model

Parameter estimates of the error correction model for the IBEX-35 spot and futures prices. γ_1 (γ_2) give the coefficient of the error correction term in a spot (future) equation and the t-statistic is in parentheses.

	22	23	24	27★	28★	29★	30
γ_1	-0.152	-0.299	-0.269	-0.150	-0.076	-0.057	-0.158
t-stat.	(-4.221)	(-6.960)	(-5.677)	(-4.562)	(-4.519)	(-3.201)	(-5.008)
γ_2	0.066	-0.053	-0.039	-0.103	-0.011	0.003	-0.098
t-stat.	(1.464)	(-0.943)	(-0.756)	(-2.309)	(-0.289)	(0.084)	(-1.911)

★Asian crisis

and the midquote of the futures contract; c_1 and c_2 are constant terms; p indicates the number of lags and z_{t-1} is the error correction term that is obtained from the following expression

$$z_{t-1} = \alpha_1 \times lpc_{t-1} - c - \alpha_2 \times lpf_{t-1}$$

where α_1 and α_2 indicate the parameters of the cointegrating vector.³⁵

The estimates of error correction coefficients in the spot (γ_1) and the futures (γ_2) equations are presented in Table 6. γ_1 is significant, negative and higher than γ_2 in absolute value for every day, while γ_2 is only significant on 27th October. These results suggest that the spot market responds to the deviation from long-run equilibrium in $(t-1)$ for every day except for 27th October, where a simultaneous adjustment is observed in the spot and futures markets.

Furthermore, the absolute value of γ_1 diminishes strongly on 28th and 29th October. This indicates a smaller response of the spot market to the disequilibrium between spot and futures prices during the Asian crisis. It is important to note that the effects of infrequent trading in stocks have been modelled through the methodology proposed by Jokivuolle³⁶ to proxy for the true index prices. The results do not differ significantly from those obtained without carrying out this adjustment and they are available upon request.

In short, the measures based on statistical and econometric techniques contradict each other when determining the absence or presence of market integration. For example, according to measure 1 ($\rho_{\text{spot-fut}}$) the markets are more integrated on 28th October than 29th October (see Table 2) while, according to measure 3, the markets

are not integrated on 28th October and they are on 29th October at the 5 per cent level (see Table 6).

Measures based on cross-market arbitrage

The study of financial integration measures based on the basic principles of assets valuation traditionally starts by measuring the degree of fulfilment of the LOP. Although the AAO is stronger than LOP (AAO implies LOP but the converse fails in a general framework), they are equivalent conditions in the particular case of a stock index and its replica (see Appendix). Consequently, the study of the fulfilment of the LOP between the futures market on IBEX-35 and its underlying asset (and the riskless asset) in fact embraces the study of all the possible arbitrage opportunities. Furthermore, Pardo³⁷ proved the equalities $g = a$ and $m = M$ in this particular context.

Measures p , g and m have been calculated for each minute of the days considered and are summarised in Table 7 (second, third, fourth and fifth rows). If we do not consider the transaction costs all the measures indicate market disintegration. The maximum disintegration is observed during 28th, 29th and 30th October. On 28th October, measure p takes the maximum and the minimum values of the period and, also, measures g and m reach their highest values. The greatest integration level is detected on 22nd, 23rd

and 24th October. We also highlight the fact that the minutes with overvaluations of spot prices with regard to the futures prices ($C_t > C'_t$) are greater than those of the undervaluations ($C'_t > C_t$) on both the Asian crash days and the other days (sixth and seventh row).

As previously explained, measures p and m allow transaction costs to be discounted. Therefore, it is possible to analyse whether disparities in the prices of the asset and its replica are, or are not, explained by them. Transaction costs have been considered for each day taking into account market fees, commissions and market impact costs in the spot and futures markets.³⁸ After performing this correction, the measures p and m lead to similar results.

In addition, the eighth and ninth rows of Table 7 show the number of detected opportunities of direct and reverse cash-and-carry arbitrage strategies. In the days prior to the crash, all (except one) of the deviations between cash and futures prices are explained by the transaction costs (arbitrage opportunities do not exist and markets are integrated). However, during 28th and 29th October, most of the deviations are not explained by transaction costs (arbitrage opportunities exist and markets are not integrated). In these circumstances, we still detect the prevalence of reverse cash-and-carry opportunities except on 30th October when the number of cash-and-carry opportunities is greater.

To sum up, the level of integration

Table 7: Measure based on cross-market arbitrage

The first column shows all measures. The rest of the columns give the results for the corresponding days. The second (third) row gives the maximum (minimum) value of p . The fourth and fifth rows show the maximum values of g and m , respectively. The sixth (seventh) row gives the number of minutes in which the contemporaneous spot price (C_i) is lower (higher) than the theoretical spot price (C'_i). The eighth row shows the number of cash-and-carry (C.C.) arbitrage opportunities. The ninth row shows the number of reverse cash-and-carry (R.C.C.) arbitrage opportunities. The transaction costs have been computed for the corresponding days.

Variable	22	23	24	27*	28*	29*	30
Maximum p	1.002382	1.002769	1.002459	1.003566	1.038149	1.004643	1.010057
Minimum p	0.997282	0.997058	0.995792	0.989183	0.970087	0.986578	0.995893
Maximum g	0.001547	0.001653	0.002358	0.005674	0.017762	0.007035	0.005316
Maximum m	0.002718	0.002942	0.004208	0.010817	0.036747	0.013422	0.009957
$C'_i > C_i$	148	100	53	202	31	53	224
$C_i > C'_i$	268	316	363	214	371	327	184
C.C.	0	0	0	0	27	4	20
R.C.C.	0	0	1	8	322	125	1

*Asian crisis

shown by the integration measures based on cross-market arbitrage coincides as much in stable periods as in volatile periods.

Measures based on equilibrium models

Finally, we have calculated the difference between the natural logarithms of the theoretical spot price and of the observed spot price and have tested whether the mispricings follow a mean reversion process (measure 10). The Augmented

Dickey-Fuller (ADF) test was used to check the presence of mean reversion in the mispricings. The results are reported in Table 8. The estimated ADF values support the absence of a unit root, with the exception of 27th and 28th October.

Hence, the mispricing series for both days are non-stationary and, according to measure 10, the markets are not integrated. For the remaining days, the mispricing series behaves as a stationary series and, therefore, the spot and futures markets are

Table 8: Mean reversion in mispricing series

Test of unit roots in mispricing series. The variable ADF represents the Augmented Dickey-Fuller test of a single unit root in the mispricing series. The critical value of ADF at 1 per cent level is -3.449. γ is the mean reversion parameter of the mispricing process and its p -value appears in parentheses.

	22	23	24	27*	28*	29*	30
ADF	-8.278	-4.645	-8.717	-1.785	-0.920	-3.549	-3.714
γ	-0.276	-0.241	-0.351	-0.074	-0.011	-0.091	-0.146
p -value	(0.000)	(0.000)	(0.000)	(0.075)	(0.358)	(0.000)	(0.000)

*Asian crisis

integrated. Note that the parameter γ is larger in absolute value for the days outside the Asian crisis period. This indicates a larger convergence from prices to the equilibrium level during those days and the presence of certain disintegration during the Asian crash.

The integration measure of Bessembinder (measure 11) has not been calculated for two reasons. First, because this measure needs long time series with low frequency and, secondly, because our empirical application includes only one futures market and 'inference with regard to asset pricing models can be sensitive to the exclusion of securities from the cross-sectional analysis' (Bessembinder, pp. 639-640²⁷).

If these results are compared with those obtained with the measures based on statistical and econometric techniques, it can be concluded that spot and futures markets were integrated in the stable

subperiod (22nd, 23rd and 24th October). Nevertheless, the results on market integration are partially contradicted in the volatile sub-period (27th, 28th, 29th, and 30th October).³⁹

The comparison with the results achieved when applying the measures based on cross-market arbitrage shows that the lower the mean reversion parameter (γ), the greater the existence of arbitrage opportunities.

CONCLUSIONS

The degree of integration among financial markets is an important issue, since the higher this degree is, the better the price discovery is. The relevance of this question explains the large number of papers that have addressed this issue for almost all kinds of traded assets. In this paper a systematisation and critical

comparison of the usual integration measures has been performed, going deeply into this topic.

One of the fundamental aspects of the paper has been the distinction between econometric and statistical measures on the one side, and measures based on the asset pricing theory on the other side. In this last group, important measures are presented, because they can provide the optimum arbitrage strategy, taking into account in addition the transaction costs. In comparison to the econometric and statistical measures that use historical data to perform an ex-post analysis, the measures based on the asset pricing theory import data from the markets allowing the prompt detection of the possible disintegration among markets, thus providing the means to exploit this anomaly.

The paper empirically tests the effectiveness of a large number of market integration measures during a period characterised by disintegration and the effect of the Asian Crisis on October 1997. The results clearly reveal that measures based on statistical and econometric techniques contradict each other in volatile periods, and that the level of integration shown by measures based on cross-market arbitrage coincides as much in stable as in volatile periods.

Hence, pricing models must be taken into account when a measure of market integration is being developed. These measures may be defined by arbitrage

methods or by equilibrium arguments. The first group is appropriate if derivative markets are involved or if hedging strategies are the main purpose of the analysis.

Instead, the second is useful to study well-diversified portfolios in incomplete markets. In any case, there are certain measures that can be applied in both types of settings.

APPENDIX

The fulfilment of the Law of One Price (LOP) and the absence of arbitrage opportunities are equivalent properties in some restricted contexts.

Let us consider two dates $t < T$ and three securities denoted by S_1 , S_2 and S_3 . S_1 will be a risk-less asset, S_2 a risky one and S_3 a futures contract on S_2 with T maturity. Suppose that S_2 does not pay any dividend between t and T and denote its price by $I(t) > 0$ at t and by $I(T) \geq 0$ at T . It is clear that $I(t)$ must be a concrete numerical value while $I(T)$ must be a random variable. As usual, $r > 0$ will represent the interest rate between t and T and, consequently, $1/(1+r)$ and 1 are the prices of S_1 at t and T respectively. Finally, denote by $F(t, T)$ the future (at T) price of S_2 that can be guaranteed by S_3 .

Lemma

Under latter assumptions, there are no arbitrage opportunities in the model if, and only if, the Law of One Price holds.

Proof

Assume that LOP holds. Then,

$$I(t) = \frac{F(t,T)}{(1+r)} \text{ or } I(t) \times (1+r) = F(t,T) \quad (1)$$

Let $x = (x_1, x_2, x_3)$ be an arbitrary portfolio composed by x_i units of S_i ($i = 1,2,3$) and denote by $P(t)$ and $P(T)$ its numerical and random prices at t and T respectively. If x were an arbitrage portfolio, then $P(t) \leq 0$ and $P(T) \geq 0$ should hold. Hence, the proof will be finished should the fulfilment of the LOP and latter inequalities lead to $P(t) = P(T) = 0$.

Obviously

$$P(t) = \frac{x_1}{(1+r)} + x_2 \times I(t) \leq 0 \quad (2)$$

and

$$\begin{aligned} P(T) &= x_1 + x_2 \times I(T) + x_3 \\ &\quad \times (I(T) - F(t,T)) \\ &= x_1 - (x_3 \times F(t,T)) + I(T) \\ &\quad \times (x_2 + x_3) \end{aligned}$$

Since $P(T) \geq 0$ must hold for any final value of the random variable $I(T) \geq 0$, future price (or payoff) of S_3 , the following inequalities have to be fulfilled.

$$x_1 - (x_3 \times F(t,T)) \geq 0 \quad (3)$$

$$x_3 \geq -x_2 \quad (4)$$

(1) and (3) lead to

$$x_1 \geq x_3 \times I(t) \times (1+r) \quad (5)$$

We obtain from (2) that

$$x_1 \leq -x_2 \times I(t) \times (1+r) \quad (6)$$

and, thus, bearing in mind (4),

$$\begin{aligned} x_1 &\leq -x_2 \times I(t) \times (1+r) \leq x_3 \\ &\quad \times I(t) \times (1+r) \end{aligned} \quad (7)$$

Therefore, (5), (7), (3) and (4) must be equalities and $P(t) = P(T) = 0$.

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